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ATMOSPHERIC STABILITY IN CFD &NDASH; REPRESENTATION OF THE DIURNAL CYCLE IN THE ATMOSPHERIC BOUNDARY LAYER

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Introduction

For wind resource assessment, the wind industry is increasingly relying on Computational Fluid Dynamics (CFD) models that focus primarily on modeling the airflow in a neutrally stratified surface layer. So far, physical processes that are peculiar to the atmospheric boundary layer (ABL), for example the Coriolis force, buoyancy forces and heat transport, are mostly ignored in state-of-the-art CFD models. In order to decrease the uncertainty of wind resource assessment, especially in complex terrain, the effect of thermal stratification on the ABL should be included in such models.

Approach

The starting point for the present study is the existing in-house CFD code EllipSys3D (Sørensen, N.N., 1995. General purpose flow solver applied to flow over hills. Technical Report Risø-R-827(EN), Risø National Lab., Roskilde, Denmark). This general purpose CFD solver has been initially developed for flow over terrain and is used for a wide range of wind energy applications. To model the flow within the ABL more appropriately, the finite-volume code is modified.

Main body of abstract

The present study considers the simulation of the diurnal cycle in the ABL. The focus is on flow over flat terrain (horizontally homogeneous flow), subjected to temporally varying surface temperatures. To account for non-neutral stratifications, the evolution equation for potential temperature is added and the effect of buoyancy is included in the turbulence model: additional terms are added to the equations for the turbulent kinetic energy (TKE) and the dissipation rate of TKE (Sogachev, A., 2009. A note on two-equation closure modeling of canopy flow. Bound.-Lay. Meteorol., 130: 423–435). Coriolis forcing is also implemented.

The resulting surface winds, temperature stratifications and TKE values are compared against observations from the GEWEX (Global Energy and Water cycle EXperiment) Atmospheric Boundary Layer Study (GABLS) taken in Kansas, USA (Svensson, G. et al., 2011. Evaluation of the Diurnal Cycle in the Atmospheric Boundary Layer Over Land as Represented by a Variety of Single-Column Models: The Second GABLS Experiment. Bound.-Lay. Meteorol., 140(2): 177-206), and against simulations of similar diurnal cycles from other atmospheric models. The evolution of the flow field during the day is satisfactorily reproduced . Nevertheless, comparison against observations raises the issue of initial and boundary conditions of numerical experiments, because perfect test cases do not occur in reality. Large scale atmospheric variations influence measured statistics, as for example apparent in the non-constant geostrophic wind during the GABLS test case.

Conclusion

The general features of the typical diurnal cycle and its representation in the model are presented and discussed. Furthermore the sensitivity of the numerical results on the forcing and the initial conditions are examined. The chosen methodology to implement stability effects into the CFD code EllipSys3D represents a promising approach and is a first step in order to extend the application of the model to stratified flow over complex terrain.